

# **Circulation of Marginal and Semi-Enclosed Seas (Sea of Japan and Related Process Studies)**

Christopher N.K. Mooers  
Ocean Prediction Experimental Laboratory (OPEL)  
Division of Applied Marine Physics  
Rosenstiel School of Marine and Atmospheric Science  
University of Miami  
4600 Rickenbacker Causeway  
Miami, FL 33149-1098  
Phone: (305) 361-4088 Fax: (305) 361-4797 Email: [cmooers@rsmas.miami.edu](mailto:cmooers@rsmas.miami.edu)

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## **LONG-TERM GOAL**

My long-term goal is to understand the circulation dynamics of marginal and semi-enclosed seas through numerical simulation. Understanding the weather-driven transient flows (especially in coastal regions), mesoscale variability, ventilation, seasonal and interannual variability, and flow interactions with the basin topography is part of this goal.

## **OBJECTIVES**

I wish to determine the “necessary and sufficient” conditions for usefully accurate numerical simulations as a prelude to the implementation of nowcast/forecast systems, which requires attention to model evaluation using observations as well as other models. For example, we need to establish the space-time resolution and amplitude accuracy requirements for atmospheric forcing of marginal and semi-enclosed seas. Given the difficulty of determining, in particular, open (lateral) boundary conditions, it is anticipated that data assimilation will be required.

## **APPROACH**

We are using the Princeton Ocean Model (POM) as implemented on a mesoscale-admitting grid (ca. 10 km resolution) and with 26 sigma levels (and with relatively high, logarithmic resolution in the surface and bottom boundary layers) for the Japan (East) Sea (JES). It is driven with surface wind stress, heat flux, and moisture flux, and with specified throughflow from the Korea/Tsushima Strait to Tsugaru and Soya Straits. The model output is compared to available data, including CREAMS I (1993 thru 1996) current meter data (from Prof. Masaki Takematsu, Kyushu U.) over the Japan Basin and now CREAMS II (1999 thru 2001) data. Using synoptic forcing, I aim to create and analyze a test dataset for the CREAMS II field experiment, then conduct model evaluations with the CREAMS II observations, and later assimilate data through the CREAMS II period to form an analysis that can be used for diagnostic studies and the analysis of observing system strategies. In my research group (OPEL), Ms. HeeSook Kang will soon defend her dissertation on simulations of wintertime ventilation and subduction in the JES; Dr. Inkwon Bang is simulating the CREAMS II period with synoptic (NOGAPS) forcing, evaluating model-data comparisons, and designing data-assimilative analyses; and

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14. ABSTRACT <b>My long-term goal is to understand the circulation dynamics of marginal and semi-enclosed seas through numerical simulation. Understanding the weather-driven transient flows (especially in coastal regions), mesoscale variability, ventilation, seasonal and interannual variability, and flow interactions with the basin topography is part of this goal.</b>					
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Dr. Francisco Sandoval is conducting model-data comparisons using CREAMS II simulations from Dr. Bang and CREAMS II observations, beginning with CTD data (from Prof. Lynne Talley, SIO).

## WORK COMPLETED

Model simulations with monthly wind and heat (and throughflow) forcing were made based on various atmospheric data sources as a prelude to making several-year runs with synoptic atmospheric forcing to explore the wintertime ventilation and deep convection issues, especially their sensitivity to atmospheric forcing and pre-conditioning.

Case studies for the first nine days of JAN 97 with NSCAT, ECMWF, and MM5 (from Dr. Shuyi Chen, RSMAS) synoptic atmospheric forcing for two Siberian cold air outbreaks and their associated atmospheric extratropical cyclones were finalized for publication and served to define the next level of scientific issues for follow-up mss for the entire month of JAN 97 and for the CREAMS II winter experiment, JAN and FEB 00.

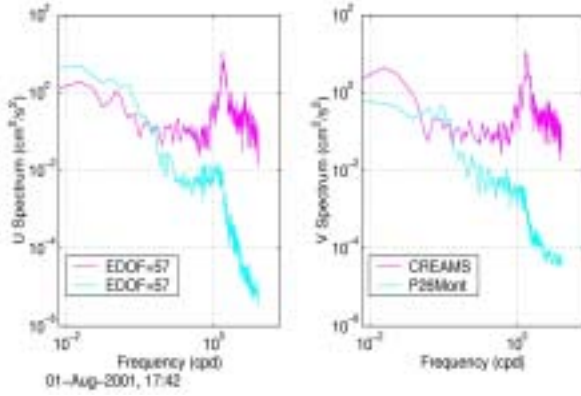
Plans have been further advanced, together with several other American, Japanese, Korean, and Russian JES modelers and observationalists, for coordinating model-model and model-data comparisons with CREAMS I and II observations; data are flowing between the various research groups.

## RESULTS

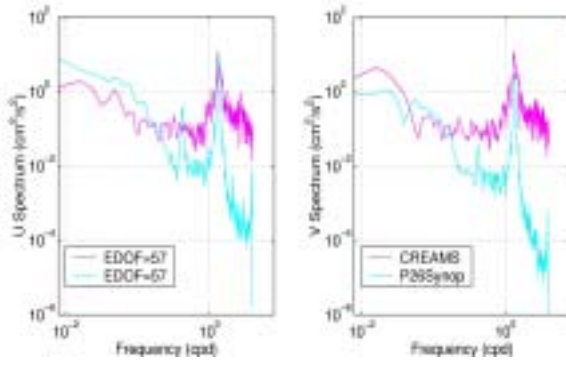
JES-POM was spun-up with ca. 11 years of Na (based on weather charts) annual mean wind stress forcing (plus relaxation to climatological surface temperature and annual mean throughflow) and then the simulations branched into two cases: one (the Na case), forcing with 10 years of Na monthly wind stress, and, two (the ECMWF case), forcing with 5 years of ECMWF (based on NWP) annual mean wind stress followed by 10 years of ECMWF monthly wind stress. Subsequently, case two has been continued with 5 years of ECMWF synoptic atmospheric forcing.

Spectra for simulated current components (Fig. 1) from three JES-POM cases with ECMWF forcing are compared to spectra computed from three years of CREAMS I current meter data (from Prof. Masaki Takematsu, Kyushu University) at a mooring (M3) in the deep Japan Basin, ca. 3,500m deep. The three cases are **mont** (monthly wind stress and heat flux forcing calculated from monthly mean fields), **empm** (monthly wind stress and heat flux forcing calculated from monthly means of synoptic (6-hourly) wind stress and heat flux), and **syn** (6-hourly synoptic wind stress and heat flux) forcing. {NOTE: surface moisture flux is estimated by relaxation to climatological monthly surface salinity.} One of the surprising results from the Japanese current meter arrays was the finding of intense near-inertial motions deep in the water column, which presents an interesting challenge for numerical simulation. At the current meter depth of 1,000 m, the **mont** and **empm** cases produce spectra that generally agree in the mesoscale band with those produced from observations, and that have shoulders or broad peaks but are two orders of magnitude too weak in the near-inertial band. However, the **syn** case produces spectra that agree well with observations in both the mesoscale and near-inertial bands at 1,000 m, but the agreement is not quite so good at 2,000 m for the near-inertial band. Thus, to the extent that near-inertial motions are important (through the vertical shears in horizontal velocity they engender) to vertical turbulent mixing and other aspects of circulation dynamics, these results point to the importance of utilizing synoptic atmospheric forcing for driving circulation models of the JES and probably other semi-enclosed seas.

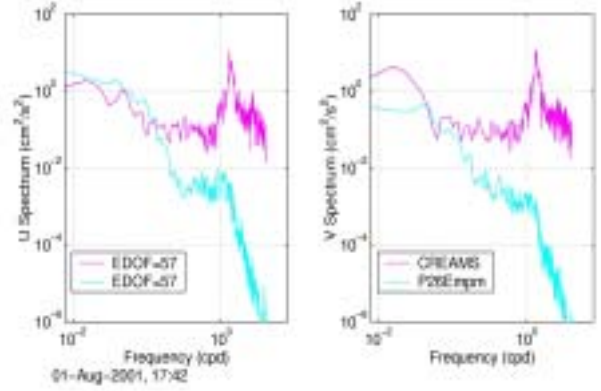
(a) CREAMS-M3/**mont**-S5 at 1000m



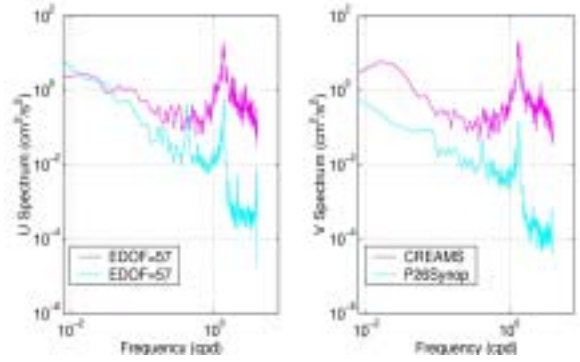
(c) CREAMS-M3/**syn**-S5 at 1000m



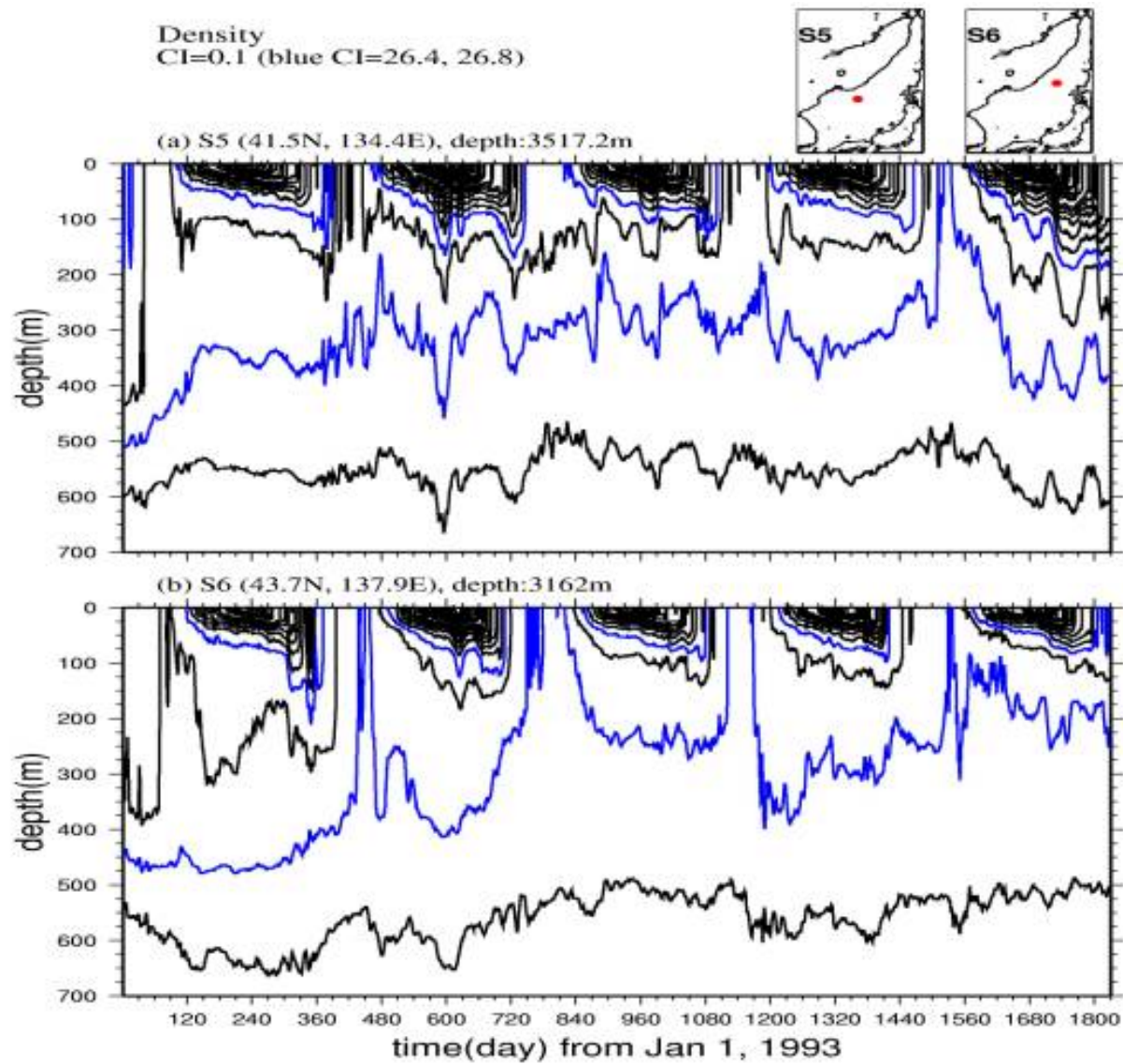
(b) CREAMS-M3/**empm**-S5 at 1000m



(d) CREAMS-M3/**syn**-S5 at 2000m



**Figure 1 Comparisons between spectra from CREAMS current meter mooring data and simulated currents at M3/S5 for August 1993 thru July 1996.**

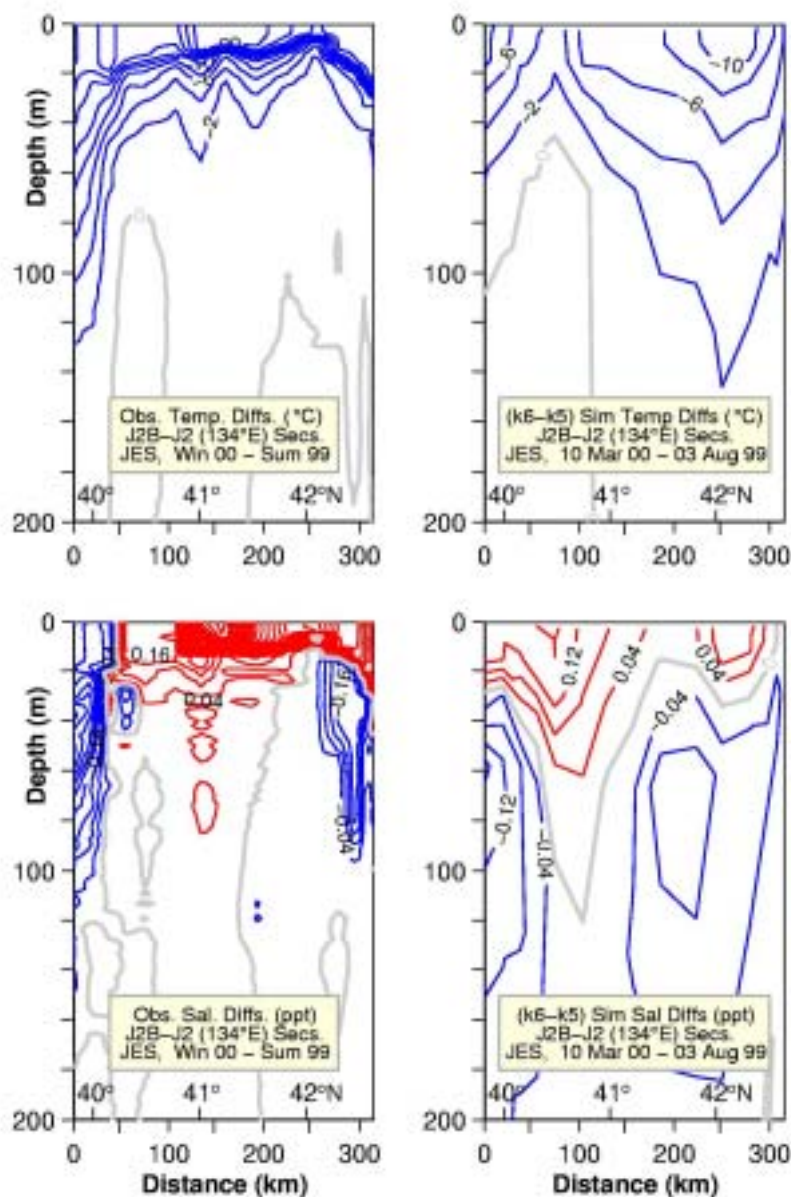


***Figure 2 Upper ocean potential density anomaly at S5 (41.5N, 134.4E) and S6 (43.7N, 137.9E) during 1993 thru 1997.***

Time-depth series of upper ocean density for five years (1993 thru 1997) of ECMWF synoptic atmospheric forcing are examined (Fig. 2) at two locations (S5 & S6) in conjectured wintertime ventilation regions over the Japan Basin and off the Primorski Coast of Russia. A fairly regular seasonal cycle of densification occurs in the upper 100 to 150 m, with evident year-to-year variability. At S5, the wintertime ventilation generally reaches to 150 m, but in 1997 it reached to 400 m; at S6, it generally reaches to 400 m, but the duration of the ventilation period varies from a few days to a month. The maximum potential density anomaly ( $\text{kg/m}^3$ ) at the surface at the time of ventilation is typically 26.8, which is lighter than the 27.3 anticipated from observations, highlighting the need to give more attention to surface moisture fluxes and advection of salinity anomalies from Korea Strait or the Primorski Coast.

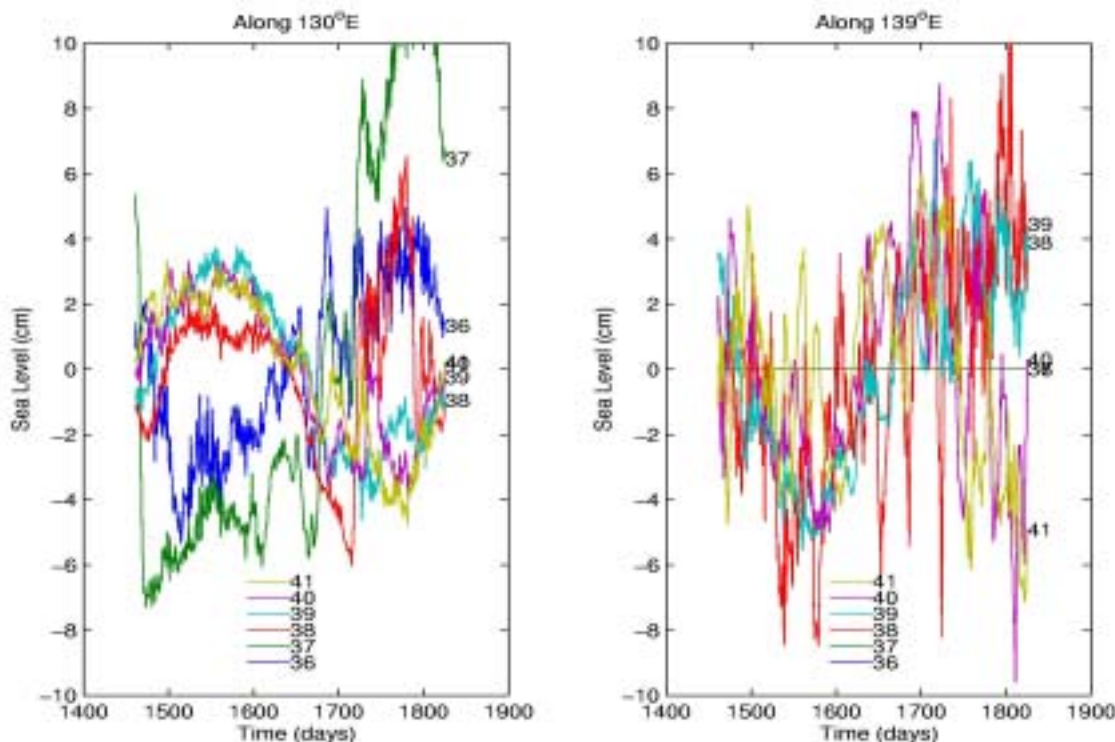


New simulations with JES-POM are underway using NOGAPS synoptic atmospheric forcing for the CREAMS II period (1 JAN 1999 thru 31 DEC 2001), initially using NOGAPS forcing for 1999 and 2000. The CREAMS II observations provide numerous opportunities for model-data comparisons; for example, it is possible to compare several quasi-synoptic CTD transects at a few times with corresponding model snapshots of temperature and salinity. For example, the seasonal changes in the upper ocean along 134E (for a 300 km interval common to both summer and winter cruises) are compared for the observations versus the model output (Fig. 3). Between 3 AUG 99 and 10 MAR 00, the simulated temperature generally cooled by 2 to 10 C in the upper 100 m, while the observed cooling was similar except that it was much greater, as much as 20C in the upper 20 m, but confined to the upper 50 m. The analogous salinity changes indicate surface (ca. upper 20 m) salinification (ca. + 0.1 ppt) and subsurface (between ca. 40 and 200 m) freshening (ca. -0.1 ppt) in both the north and the south, though the range of the observed changes is about twice that of the simulations. While the individual transects indicated that the Sub-Polar Front and Jet (SPFJ) was located at 40 to 41N for both observations and simulations, the observations were substantially warmer and saltier than the simulations in the upper 100 m south of the SPFJ, an issue that is under further investigation. Time series of simulated SSH at 36, 37, 38, 39, 40, and 41 N along 130E (i.e., in western JES) and



**Figure 3. Seasonal cooling and salinification trends from summer 1999 to winter 2000 along 134E for CTD observations from Prof. Lynne Talley, SIO and JES-POM simulations with NOGAPS synoptic forcing.**

along 139E (i.e., in eastern JES) are examined for 1999 (Fig. 4). The salient characteristics are (1) a seasonal cycle with an amplitude of ca. 5 cm; (2) the seasonal cycle is in-phase north-to-south along 139E, but out-of-phase between north-and-south along 130E and in-phase in the south between eastern and western sides; (3) intra-seasonal and mesoscale variability of several cm, and (4) a background noise of synoptic (weather cycle) variability of a few cm. It will be possible to evaluate some aspects of this simulated SSH variability in comparison to Topex/Poseidon SSH data. However, the T/P SSH data are aliased by the synoptic scale variability demonstrated here and fuller analysis of the model output will serve to better define the JES sampling environment that may limit interpretation of T/P SSH data.



**Figure 4. Simulated sea surface height (SSH) time series (from JES-POM with NOGAPS synoptic forcing) during 1999 at 36, 37, 38, 39, 40, and 41N along 130E and 139E.**

## IMPACT/APPLICATIONS

The model-data comparison presented for CREAMS I and CREAMS II timeframes demonstrate that simulations with synoptic forcing can be rationally compared with available observations; i.e., the simulations are in sensible ranges and available observations are useful for these purposes. Furthermore, the point has been reached where (1) useful feedback is being provided to the simulation efforts from the comparisons with observations, (2) the confidence in the verisimilitude of the simulations is sufficient to diagnose aspects of the wintertime ventilation and subduction, and (3) useful assessments of observing systems are in prospect.

## PUBLICATIONS

(2000) (with H. S. Kang) Simulation of the Variability of the Subpolar Front and Jet in the Japan (East) Sea. In: *Oceanic Fronts and Related Phenomena (Konstantin Federov International Memorial Symposium)*, IOC Workshop Report, 159, UNESCO, Paris, 359-366.

(in press) (with L. Gao, W. D. Wilson, W. Johns, K. Leaman, H. Hurlburt, and T. Townsend) Initial Concepts for IAS-GOOS. In: *Operational Oceanography* [Extending the limits of predictability, Second EuroGOOS Conference] (Ed. N. Flemming). Elsevier, New York.

(2001) (with H. S. Kang and S.S. Chen) Several Aspects of the Simulated Response of the Japan (East) Sea to Synoptic Atmospheric Forcing due to Siberian Cold Air Outbreaks. *La mer*, 39(1).

(in press) (with S. L. Vaughan and S. M. Gay III) Physical Variability in Prince William Sound during the SEA Study (1994-1998). *Fisheries Oceanography*.

(resubmitted) (with I. Bang) The Influence of Several Factors Controlling the Interactions between Prince William Sound, Alaska and the Northern Gulf of Alaska. *J. of Physical Oceanography*.